

## Bendbots

*UNLIKE HUMAN HANDS*, which move simply by contracting and relaxing muscles, robotic arms use gears, hydraulics, and other expensive, heavy, power-hungry parts. In future NASA planetary exploration missions--where robots will need to carryout simple tasks of sample collection and manipulation--such complexity becomes a problem. Heavy items cost more to launch, and power suppliers are limited on space systems. All this motivated Yoseph Bar-Cohen to try to make a better robot. And he may have succeeded. Under a NASA Telerobotic task, so-called Low-Mass Muscle Actuators (LoMMAs), he has now two types of artificial muscles that quickly respond to small amounts of electricity by lengthening or bending, almost like the real thing.

Bar-Cohen, a physicist at Caltech's Jet Propulsion Laboratory, has established an interdisciplinary team to develop two different types of **electroactive polymer (EAP)** actuators and to tackle issues that hamper their applicability. The team consists of Sean Leary of JPL, Mohsen Shahinpoor of the University of New Mexico, Joycelyn Simpson and Joseph Smith of NASA LaRC as well as Richard Claus of Virginia Tech. The first EAP actuator works as the fingers of human hands. The actuator is a flexible polymer ribbon constructed from chains of carbon, fluorine, and oxygen molecules. When an electric field is applied, positive and negative charges are produced on both sides of the ribbon, the positive ions are repelled by the positively charged particles on one side whereas the negatively charged are attracted to the positive charges on the other side. This results bending toward the side of the negative electrode. Using a single ribbon, as shown in Figure 1, Bar-Cohen constructed a **surface wiper** for dust removal from solar cells and from windows of instruments. Using four such ribbons, a **gripper** was fashioned to pick-up rocks as shown in Figure 2.

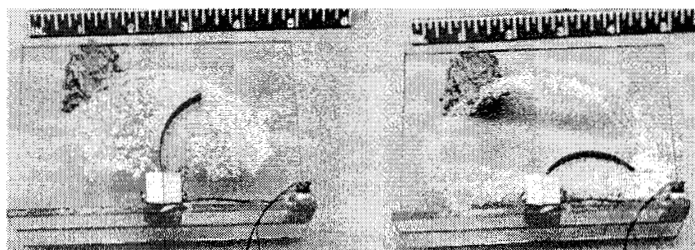


Figure 1: Dust removal using a bending EAP ribbon.

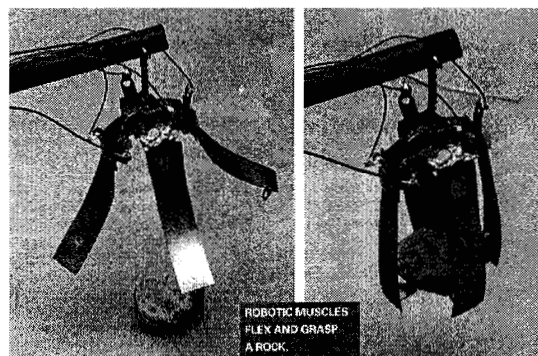


Figure 2: Robotic EAP end-effector grabbing and holding a rock.

The other type of EAP actuator consists of thin sheets that are wrapped into a cigar-like cylinder. This polymer stretches when one side of a sheet is given positive charges and the other negative. These charges cause the wrapped sheet to contract toward the center of the cylinder, and this contraction causes the cylinder to expand lengthwise. When the power supply is off, the rope relaxes. Such cylindrical EAP actuators emulate the action of muscles and they were used to lift loads using a **robotic arm** as shown in Figure 3.

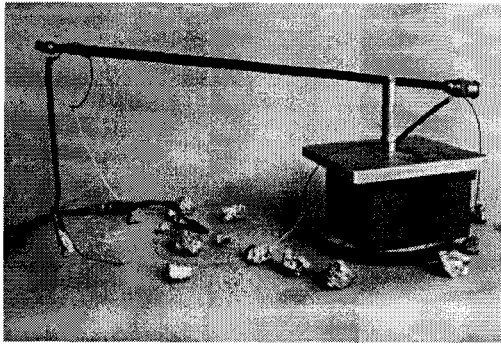


Figure 3: A robotic arm that is dropped and lifted by EAP actuator.

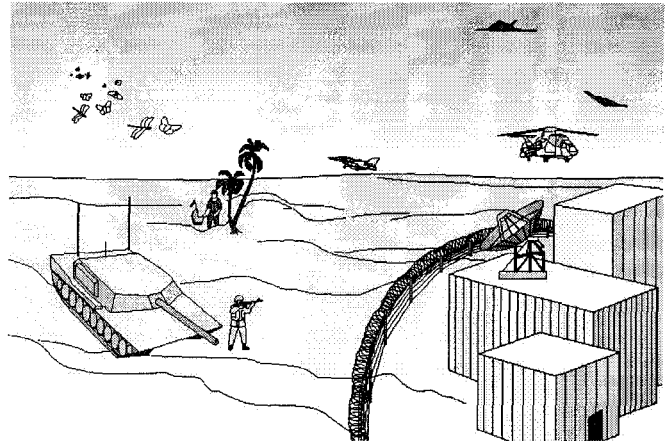


Figure 4: Flying and other insect-like robots can change the battlefield of the future.

Under his LoMMAs Telerobotic task, Bar-Cohen is continuously searching for effective EAP actuators and avenues for their applications. Examples of alternative polymers that are currently being considered include a polymer gel that is being developed by Paul Calvert at the University of Arizona as well as the bending polypyrrole by Toribio Otero from Basque University, Spain. To enhance the robustness of EAP actuators, various processing and coating techniques are investigated, including the inkprinting method of controlled application of polymer materials. This effort is conducted in coordination with David Wallace of MicroFab Technologies. Also, a unique coating and electroding technique is investigated with Richard Claus of Virginia Tech using his self-assembled monolayering method. To establish miniature instrumentation and devices, micro-electro-mechanical systems (MEMS) technology is being considered jointly with Chang Liu of University of Illinois at Urbana-Champaign. Moreover, the development of miniature insect-like robots is explored with Michael Goldfarb of Vanderbilt University. Insect-like robots offer many potential applications in such areas as space, military, medical and others. A cartoon view of a potential military application in the form of butterflies and dragonflies for surveillance to support soldiers in a battlefield is shown in Figure 4.

To promote the growth of this field, Bar-Cohen has taken an initiative jointly with SPIE to start series of conferences on this subject. The conference is entitled "Electro-active Polymer Actuators and Devices (EAPAD)", its code is (SS04), and we be part of SPIE's 6th Annual International Symposium on Smart Structures and Materials. This conference will be held at Newport Beach, CA from March 1 to 5, 1999. More information is available on homepage address: <http://www.spie.org/web/meetings/calls/ss99/ss04.html>

The electroactive polymer actuators that Bar-Cohen is using are cheap, durable, and driven by fraction of watt power. However, there's a drawback: they don't produce a large force. He is working on that, but for now he's sticking to minirobots that can lift about a third of an ounce. That should be sufficient if, as Bar-Cohen hopes, his polymer actuators are incorporated into the five-inch rover, JPL is building for asteroid exploration. "I see it as an evolution, like the car or the first computer," says Bar-Cohen. "Once you make something like this, there is no end to it."

Further information regarding the JPL's Telerobotics Task LoMMAs is available on the web-hub address <http://ndea.jpl.nasa.gov/> under the category Advanced Actuators.